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STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
DIVISION OF THE
STATE GEOLOGICAL SURVEY
FRANK W. DE WOLF, Chief

EXTRACT FROM BULLETIN No. 44

A RESTUDY OF THE STAUNTON GAS POOL

BY
L. A. MYLIUS

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS
1919

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A RESTUDY OF THE STAUNTON GAS POOL

By L. A. Mylius

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INTRODUCTION

ACKNOWLEDGMENTS

These reports are developed from two short visits to the pool in April and May 1919, from previous published reports, Oil and Gas in Bond, Macoupin and Montgomery counties[1], Oil and Gas in Gillespie and Mount Olive quadrangles[2], Petroleum in Illinois 1914 and 1915[3], and from information kindly given by Mr. L. H. Miller, Mr. Virgil Bachelor, Mr. T. A. Rinaker, the Cahokia Pipe Line Company, the Ohio Oil Company, and others. In interpreting data on the underlying strata the writer was guided chiefly by Dr. T. E. Savage.

The information on the whole was general and considerable difficulty was experienced in studying all conditions met with in the pool area.

The contour maps are developed from coal tests and skeleton logs which in most cases gave the position of No. 6 coal and the top of the sand.

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[1]Blatchley, R. S., Oil and Gas in Bond, Macoupin, and Montgomery counties: Ill. State Geol. Survey Bull. 22, p. 41, 1913.

[2]Lee, Wallace, Oil and Gas in Gillespie and Mount Olive quadrangles: Ill. State Geol. Survey Bull. 31, p. 101, 1914.

[3]Kay, F. H., Petroleum in Illinois 1914 and 1915: Ill. State Geol. Survey Bull. 33, p. 80, 1916.

The graphs on pressure and flow were developed from two incomplete sets of figures. Although these figures cannot be guaranteed correct in any one detail, it is believed that they represent very well the general behavior of the pool.

Purpose

The object of these notes in the order in which they appear is:

1. To study the structure from well logs now available.
2. To study the decline in gas pressure and flow.
3. To study the sands.
4. To ascertain if possible the extent to which the field has been and is being handicapped by water trouble.
5. To present considerations for future drilling.

Location

The present gas pool covers parts of secs. 13, 14, 15, 22, 23, and 24, Dorchester Township, Macoupin County. The S½ of sec. 14, the center of the pool, is about three and one-half miles northwest of Staunton.

History

Illinois State Geological Survey Bulletin 33 covers the early history of this pool[1]. At that time seven wells had brought in gas. In August 1916 the Cahokia Pipe Line Company started to operate and began taking gas from the pool.

Most of the wells were drilled prior to 1917, but were turned into the pipe line at different times later on. The falling off of the gas late in 1918 stimulated the drilling of new wells mostly in the proven area. In all to date, May 1919, 26 wells gave gas in greater or less amounts, but only 19 have been turned into the pipe line.

L. H. Miller Oil and Gas Company, Miller Brothers Oil and Gas Company, Superior Oil and Gas Company, Miller Estate Oil and Gas Company, Lambert and Fleeger, and Bachelor Brothers, all of Staunton; Ibbotson and Rinaker, Carlinville; Monks Mound Oil and Gas Company, St. Louis; C. H. Turner, Casey, Illinois, are parties interested.

The Cahokia Pipe Line Company of East St. Louis, has lines to Staunton, Edwardsville, Collinsville, East St. Louis, and Belleville. About December, 1918, compressors were installed at Edwardsville to overcome the disadvantage of low pressure in the pipe line. On April 23, 1919, permission was obtained by the above company to restore artificial gas service in Edwardsville.

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[1]Kay, F. H., Petroleum in Illinois 1914 and 1915: Ill. State Geol. Survey Bull. 33, p. 80, 1916.

GEOLOGY

General Section

The accompanying section is compiled from a study of the underlying strata from well logs, samples of drillings, and publications on the adjoining counties and the general vicinity of Staunton.

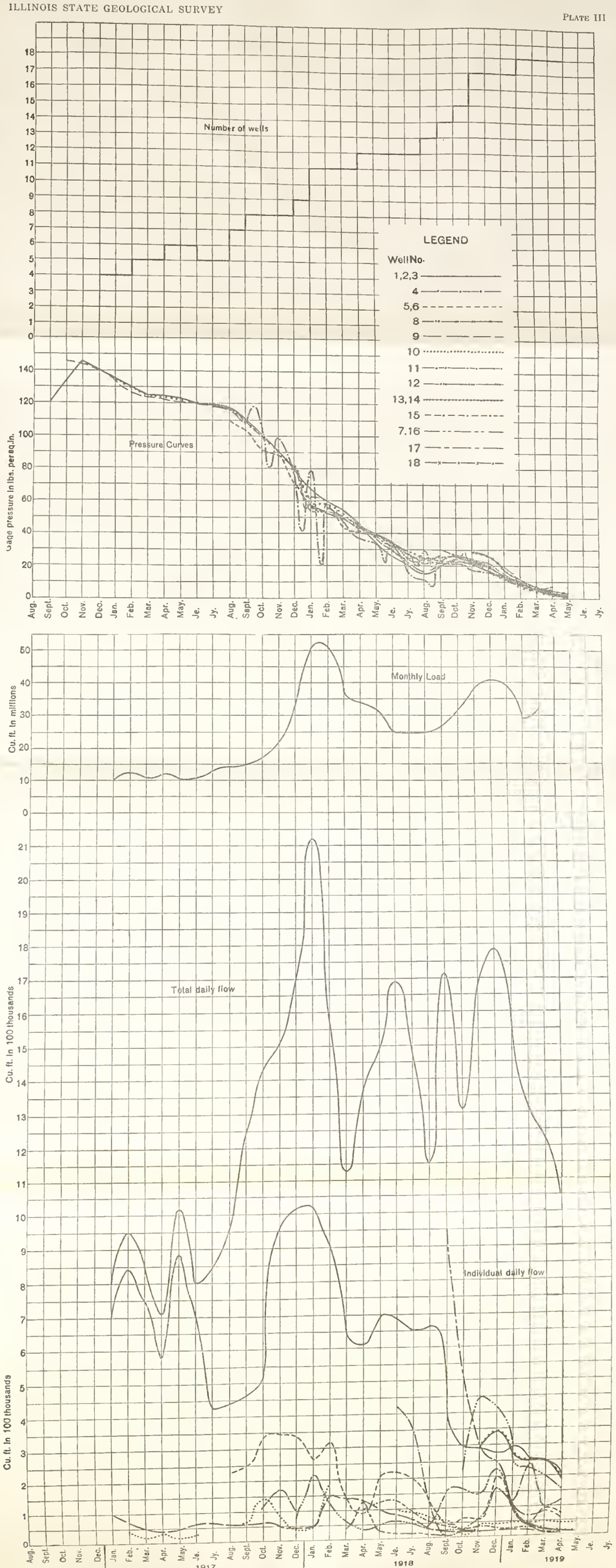
Log of Well No. 8

The accompanying log of well No. 8 shows to a depth of about 1500 feet, the character of the strata in the immediate vicinity of the Staunton dome.

Log of Well No. 8[1], Ohio Oil Company, on the George Groves farm in sec. 15, Dorchester Township

	Thickness *Feet*	Depth *Feet*
Water		at 15
Shale, blue	50	126
Lime	2	128
Shales, dark muddy	21	149
Lime	1	150
Slate, blue	20	170
Slate, sandy	25	195
Lime	4	199
Shale, blue	16	215
Lime	15	230
Shale	7	237
Lime	5	242
Coal, *No. 6*	6	248
Lime	8	256
Shale, blue	10	266
Lime	20	286
Shale, hard black	44	330
Shale, blue	6	336
Shale, white	84	420
Shale, blue	43	463
Sand (gas)		at 463
Gas	12	475
Showing of oil	7	482
Water, salt	28	510
Shale, brown	20	530
Sand, salt	70	600
Showing of green oil		at 565
Sand, water	35	600
Lime, *"Big Lime"*	300	900
Sand, black, and shale	45	945
Slate and sand	70	1015
Lime, white	205	1220
Lime, black	50	1270
Red rock	5	1275
Lime, blue	10	1285
Lime, red	15	1300
Shale, red	8	1308
Lime, of various colors	27	1335
Slate, black	25	1360
Slate, sandy	40	1400
Shale, black	10	1410
Shale, brown	15	1425
Sand	25	1450
Lime, *Niagaran*	50	1500

[1]Well numbers here and throughout the report have reference to those used on the map, Plate I, and in the Table of Well Data.



Flow and pressure curves for wells on the Staunton dome, September, 1916 to May, 1919.

STRUCTURE OF THE STAUNTON DOME

The records of most of the wells drilled since 1915 give the depth to No. 6 coal. This enables the structure of the coal to be shown in more detail on the accompanying map, Plate I, than was possible at the time Plate IX of Bulletin 31[1] was published.

The long axis of the dome runs about 40 degrees west of north from the center of sec. 24 to the center of sec. 10, T. 7 N., R. 7 W. The beds dip at a higher angle on the northeast side of the dome than on the southwest side. The highest and widest part of the dome is mainly in sec. 14. The beds continue high toward the northwest from sec. 14, but drop considerably toward the southeast.

No contours are drawn in the outlying sections as the data now available do not show any decided signs of new anticlinal structure. The actual structure in sec. 24 is not very clear as yet.

TABLE OF WELL DATA

Table I contains most of the well detail in a form that is hoped will allow comparisons between the different wells. The wells are numbered to simplify reference. All figures used, pertaining to wells, in the body of this paper are taken from the accompanying table.

GAS PRESSURE AND FLOW

The flow and pressure curves (Plate III) are developed from two sets of figures for the same wells which when compared do not always check. The pressure readings after the pressure became as low as 15 pounds are not accurate, as the meter installations were for considerably higher pressures.

The lowest group of curves on Plate III was made up by taking an approximate day's flow from each well or set of wells on the same meter, each month. The total daily flow immediately above was drawn using the totals of the individual curves. The load curve does not represent the total output per month, but is introduced to show the sensitiveness of the well behavior to the load. The curves showing pressure, gaged in pounds per square inch, agree closely and are *all* plotted to bring out that point. The graph for the number of wells represents the number turned into the pipe line.

The initial gage pressure of the early wells was from 155 to 160 pounds per square inch. Up until January, 1917, only about 16,000,000 cubic feet of gas was drawn from the pool and the drop in pressure to 135 pounds would indicate considerable waste. From January, 1917, to July, 1917, five wells (3 graphs) were supplying gas. A rather gradual drop in pressure resulted from 135 to 120 pounds. In August the introduction of Nos. 5 and 6 seems to have taken a big part of the load from Nos. 1, 2, and 3, due probably to temporary slightly higher pressure, but from October the flow of all the wells with the exception of No. 9 rose to meet the increasing load which had its peak in January, 1918, when nine wells were producing and the pressure had dropped to about 60 pounds. The steepening of the pressure decline

[1]Lee, Wallace, Oil and Gas in Gillespie and Mt. Olive quadrangles: Ill. State Geol. Survey Bull. 31, p. 101, 1915.

TABLE I.—*Table of well data*

Well Number[a]	LOCATION ¼	LOCATION Sec.	PROPERTY	Surface elevation	No. 6 coal Depth to top	No. 6 coal Elevation of top	SANDS Depth to top	SANDS Elevation of top	SANDS Elevation of best pay
	Dorchester Twp.								
46	9	NW	F. Stamme	646	.....	.....	.....	.....	.....
[b]15	9	NE	Superior Coal Co.	645	309	336	.....	.....	.....
[b]17	10	NE	do	645	297	348	.....	.....	.....
[b] 7	10	NE	do	639	310	329	.....	.....	.....
[b]22	10	SE	do	644	306	338	.....	.....	.....
36	12	NW	C. C. Isaacs	634	289	345	502	132	.....
34	13	SE	C. Schmutzler	551	230	321	.....	.....	.....
18	14	NW	Miller Estate	580	222	358	416	164	148
47	14	NE	Wall	621	.....	.....	.....	.....	.....
33	14	NE	J. Coatney	613	296	317	.....	.....	.....
19	14	SW	Harrison Woolridge	611	247?	364	467	144	109
10	14	SW	do	613	.....	.....	.....	.....	.....
1	14	SW	Dan Groves	612	245	367	441	171	.....
3	14	SW	do	611	248	363	464	147	.....
4	14	SE	Schoolhouse	612	252	360	480	132	122
16	14	SE	Godfrey	609	257	352	482	127	.....
7	14	SE	do	610	.....	.....	.....	.....	120?
12	14	SE	Alonzo Woolridge	612	257?	355?	512?	101?	.....
44	15	NW	C. Schweitzer	621	285?	336?	.....	.....	.....
8	15	NW	George Groves	574	242	332	461	113	111
20	15	NE	Lancaster	612	268	344	476	136	121
17	15	NE	Rice	613	260	353	476	137	124
21	15	NE	Brockman	596	240	356	441	155	118
32	21	NE	A. Bauer	588	248	340	496	92	.....
[b] 8	22	NW	Superior Coal Co.	609	276	333	.....	.....	.....
30	22	NE	Shrier	595	243	352	.....	.....	.....
9	22	NE	A. Fletcher	608	260	348	470	138	.....
2	23	NW	D. Groves	612	247	365	442	170	152
13	23	NE	Superior Coal Co.	610	247	363	464	146	.....
14	23	NE	do	609	249	360	462	147	.....
[b]11	23	NE	do	609	249	360	.....	.....	.....
5	23	NE	Hamp Woolridge	585	224	361	430	155	.....
6	23	NE	do	608	246	362	485	123	.....
15	23	NE	Harrison Woolridge	609	256	353	489	120	.....
22	23	NE	V. Schweitzer	605	260	345	462	143	116
42	23	SW	E. G. Wilder	601	273	328	.....	.....	.....
43	23	SW	Sawyer	.....	.....	.....	.....	.....	.....
29	23	SE	A. G. Schnaare	600	270	330	465	135	.....
27	24	NW	H. Adler	571	240	331	453	116	.....
28	24	NW	do	581	251	331	487	94	.....
23	24	NW	do	534	205	329	429	105	.....
45	24	SW	Blank	.....	.....	.....	.....	.....	.....
26	24	NE	L. Schnaare	531	.....	.....	.....	.....	.....
25	24	SW	do	532	200	332	440	92	.....
24	24	SE	do	529	185	344	417	112	.....
[b]	24	center	Superior Coal Co.	531	.....	331	.....	.....	.....
11	24	SW	E. D. Wilder	530	202	328	424	106	.....
40	25	SW	N Smith	532	195	337	426	106	.....
39	25	SE	D. Funderburk	599	260	339	510	89	.....
38	25	SE	do	533	195	338	445	88	.....
[c]	25	SE	.....	552	202	340	.....	.....	.....
[b]10	26	SW	Superior Coal Co.	589	242	347	.....	.....	.....
31	27	NE	C. Bruhn	600	265	335	520	80	.....
[b] 9	28	SE	Superior Coal Co.	590	242	348	.....	.....	.....
				.....	.....	.....	.....	.....	.....
	Staunton Twp.			.....	.....	.....	.....	.....	.....
				.....	.....	.....	.....	.....	.....
35	19	NW	.....	553	.....	353	.....	.....	.....
37	19	NW	Dingerson	.....	.....	.....	.....	.....	.....
[c]	30	NW	.....	616	275	341	.....	.....	.....
41	30	SW	Miller	604	.....	.....	517	87	.....

[a] Well numbers refer to those used on the map, Plate I, and throughout the report
[b] Coal bore
[c] Mine shaft

for the Staunton gas pool.

SANDS		Depth of hole	Interval between top of No. 6 coal and:				Original rating in 100 M cu. ft. of gas per 24 hours	REMARKS
Elevation of oil show	Thickness		Top of sand	Best pay	Oil show	Bottom of hole		
.....	.....	592	.....	.....	.....	.....	.....	Dry
.....	.....	317	.....	.....	.....	.....		
.....	.....	305	.....	.....	.....	.....		
.....	.....	319	.....	.....	.....	.....		
.....	.....	405	.....	.....	.....	.....		
.....	.....	511	213	.....	.....	222	.....	Into salt water; dry hole
.....	.....	660	.....	.....	.....	330	.....	Dry
.....	44+	460	194	210	.....	238	.....	Producer; sand broken
.....	.....	.....	.....	.....	.....	.....	.....	Dry
.....	.....	545	.....	.....	.....	249	.....	Dry
.....	.....	515	220	255	.....	268	.....	Part time producer; water
.....	.....	.....	.....	.....	.....	.....	4500	Producer
.....	24+	465	196	.....	.....	220	4327	Producer
.....	36+	500	201	.....	.....	252	25061	Producer
.....	24+	504	228	243	.....	252	5200	Producer
.....	18+	500	225	.....	.....	243	3500	Producer
.....	.....	515	.....	.....	.....	.....	7670	Producer
.....	.....	525	244	.....	.....	268	6240	Producer
.....	.....	615	.....	.....	.....	330	.....	Dry
96 }					{ 236			
9 }	19	1500	219	221	{ 323	.....	2200	Producer; salt water
93	24	521	208	223	251	253	.....	Gas; into water
.....	.....	516	216	229	.....	256	3500	Producer
101	31	497	201	238	255	257	2700	Gas; had "fire clay," 472-78
.....	.....	571	248	.....	.....	323	.....	Dry
.....	.....	283	.....	.....	.....	.....		
111 }					{ 241			
67 }	.....	528	.....	.....	{ 195	285	.....	Dry; into a little water
.....	251	495	210	.....	.....	235	5460	Producer
.....	.....	490	195	213	.....	243	9528	Producer
.....	36+	500	217	.....	.....	253	.....	Producer
.....	38+	500	213	.....	.....	251	.....	Producer
.....	.....	258	.....	.....	.....	.....		
.....	40+	470	206	.....	.....	246	10000	Producer
.....	12?	507	239	.....	.....	261	.....	Producer
.....	16+	506	233	.....	.....	250	10630	Producer
.....	.....	520	202	.....	.....	260	235	Show of gas
.....	.....	510	.....	.....	.....	237	.....	Dry
.....	.....	.....	.....	.....	.....	.....	.....	Dry
.....	20	610	195	.....	.....	340	.....	Show of gas
96	20	480	215	.....	235	240	.....	Show of gas
91	13	506	237	.....	240	255	.....	Show of gas; into water
.....	18	447	224	.....	.....	242	1500	Gas
.....	.....	.....	.....	.....	.....	.....	.....	Dry
.....	.....	.....	.....	.....	.....	.....	.....	Show of oil
.....	.....	466	240	.....	.....	266	.....	Show of oil
85	6?	450	232	.....	259	265	.....	Show of oil
.....	.....	.....	.....	.....	.....	.....		
.....	.....	444	222	.....	.....	242	786	Producer; good oil show
.....	.....	474	231	.....	.....	279	.....	Dry
.....	.....	671	250	.....	.....	411	.....	Dry; into salt water
88	8	474	250	.....	250	279	.....	Dry
.....	.....	.....	.....	.....	.....	.....		
.....	.....	249	.....	.....	.....	.....		
.....	.....	525	255	.....	.....	260	.....	Dry; into salt water
.....	.....	.....	.....	.....	.....	.....	.....	
.....	.....	.....	.....	.....	.....	.....	.....	
.....	.....	.....	.....	.....	.....	.....	.....	
.....	.....	.....	.....	.....	.....	.....	.....	Dry
.....	.....	.....	.....	.....	.....	.....		
.....	.....	601	.....	.....	.....	.....		Show of gas; into salt water
.....	.....	.....	.....	.....	.....	.....	.....	
.....	.....	.....	.....	.....	.....	.....		Dry

started about September when the load commenced to increase. The pressure curve of well No. 4 shows evidence of water trouble. In May 1918, with 12 wells producing and with the lighter summer load the pressure had dropped to about 40 pounds. All wells except No. 11 showed a considerable reduction in flow on the turning in of well No. 17 in September. In November, 1918, when the winter load began to be felt, there were 15 wells and in December, 17 wells producing, and the pressure had dropped to about 20 pounds. With 17 wells during the rest of the season the flow fell considerably below the winter of 1917-18 when 9 to 11 wells were producing. The temporary recovery of pressure from August, 1918, to December was probably due to new wells, notably Nos. 17, 8, 13, and 14, taking the load and giving the other wells a chance to "come back" while they expended their slight advantage of pressure. In April, 1919, the pressure was down to 4 to 5 pounds when with 18 wells the flow was lower than at any time since August, 1917.

An approximate figure for the production of gas to May, 1919 would be 1, 050,000,000 cubic feet. Of this amount the central group of wells (S½ sec. 14 and N½ sec. 23) supplied about 87 per cent, the northwest group (NE¼ sec. 15) supplied about 10½ per cent, and the southeast group (sec. 24) supplied about 2½ per cent.

SANDS

Contours

The contours on the top of the sand (Plate II in pocket) agree closely with those of No. 6 coal (Plate I) and show that the coal contours defined the productive gas sand area.

Thickness

The sands appear to vary considerably in thickness being best developed at the top of the dome. This has caused the sand contours to be more accentuated than the coal, notably at Nos. 1, 2, 5, and 18. On the highest contours No. 2 seems to be the only well that has gone through the sand; it showed 48 feet. Nos. 3 and 13 were still in sand after penetrating 36 feet, No. 14 after 38 feet, and No. 5 after 40 feet. As regards the probability of a second sand the only definite break recorded is in well No. 21 where 6 feet of "fire clay", following 31 feet of sand, came before a second sand which showed oil. Well No. 20 also seems to show a break below 24 feet of upper sand. The sands thin somewhat on the edges of the dome. Nos. 8 and 27 show 19 and 20 feet of sand respectively with oil shows near the bottom and well No. 29 shows 20 feet of sand. Either the two sands have run together or the break was missed. Well No. 24 shows gas in 6 feet of sand and oil in a sand 25 feet deeper. The average interval between the top of the gas sand and the top of No. 6 coal is 218 feet while the average interval for eight "oil shows" is 246 feet. In places at least two distinct sands appear, and it is possible they run together in other

places. The depths of the gas sand and the "oil shows" below No. 6 coal seem to indicate that each constitutes a separate horizon. That shale or other rock replaces the sand in places is perhaps shown by Nos. 18 and 30 where the sands were broken and by well No. 24 which has about 6 feet of gas sand and an oil show in a sand 25 feet lower but at the horizon of the other oil shows.

Distribution

In the central group of producing wells, secs. 14 and 23, the sands seem to be thickest. This group produced about 87 per cent of the gas up to May, 1919. In consulting the curves it is very evident that the pressure and flow of all of these wells were in very close sympathy. Going toward the northwest group which produced 10½ per cent of the gas, the sands appear fairly thick, but in places broken and tighter. Gas connection undoubtedly exists between the northwest group and the central group but it is restricted to a certain extent. Going southeast toward the group in sec. 24 the contour drops about 30 feet and the sands become somewhat thinner. Only one well has produced from this southeast group and its behavior shows that the sand is more isolated than is the sand of the northwest group. However, all new wells over the whole pool, in most cases having a few pounds more pressure than the operating wells when turned in, dropped very quickly to general pool conditions of pressure and flow.

The dry holes in and around the dome show the presence of the sand, and some farther away, namely Nos. 38, 39, and 40, also show sand at approximately the same distance below the coal as the sand in the producing wells.

Porosity

As would be expected, the structure has had very marked effect on the gas production. The producing wells with two exceptions are all on the high contour. The physical condition, chiefly the porosity, of the sand also affects gas accumulation as shown by some dry holes on relatively high structure. Some wells that encountered the top of the gas sand at higher elevations than neighboring wells were not so good producers. This porosity may account for the two gassers on the lower contour but both these wells, Nos. 8 and 11, are also more isolated and have not had to "share their gas" to the same extent as other wells. It would seem that the sands in places have one or more highly porous layers. This fact caused a considerable lowering of pressure and exhaustion of the gas by the first wells in the central group; later, new wells brought increased flow for very short periods only, and some wells have proved quite insignificant that would have given a good flow had they been among the first drilled in the group.

Considerations on the Extent of Exhaustion

Before considering the extent of exhaustion of the gas in the present gas sand at Staunton, the following notes on the closed-pressure method of estimating exhaustion which cover many con-

ditions are reprinted from the Manual for the Oil and Gas Industry published by the U. S. Treasury Department, 1919:[1]

CLOSED-PRESSURE METHOD

"Because of its general applicability, the closed-pressure method is by far the best method of estimating the depletion of gas properties.

"Unfortunately, accurate closed-pressure data have not been kept for all properties or perhaps even for the majority of properties, but the rock pressure in most pools is known or is ascertainable with a fair degree of accuracy, and the information drawn from the pressure decline is, with the exception of a few fields, not subject to profound modification, because of factors whose value can not be appraised. The basis of this method is Boyle's law. According to this law of physics, if gas is pumped into a vessel until the pressure is 200 pounds and then is drawn off until the pressure is 100 pounds, the size of the vessel remaining fixed, and ignoring for the moment atmospheric pressure, it may be concluded that one-half of the gas has been drawn out of the vessel. If an underground gas reservoir of fixed dimensions is tapped by wells and the pressure is found to be a thousand pounds, and then if the gas is drawn off through the wells until the gas pressure in the pool is lowered to 100 pounds, we may infer that about nine-tenths of the supply of gas has been exhausted."

CORRECTIONS AND REFINEMENTS OF CLOSED-PRESSURE METHOD

"Several corrections and more or less important refinements are made in applying this method to the computation of depletion, and it should be borne in mind that it does not afford data on the *amount* of gas originally in the pool or at any later specified time, but only the *fraction* of the gas that has been removed from its natural reservoir and the fraction remaining in that reservoir. Perhaps the most important of these corrections arises out of the fact that the size of the reservoir does not remain fixed but becomes smaller as the gas is drawn and water or oil advances into a part of the space formerly occupied by the gas. The pressure is thus prevented from declining at a rate proportionate to the amount of gas drawn from the pool. The correction on account of water or oil encroachment is difficult to make, because of the lack of data to determine the extent of the encroachment. However, in a good many pools, after a study of the distribution of wells that have been "drowned out" and the history of water troubles in similar near-by pools, it is possible to make allowance for water or oil encroachment which will more or less closely approximate the facts.

"Another refinement applicable to the computation of depletion of natural gas by the closed-pressure method is based upon the fact

[1]Manual for the oil and gas industry, Revenue Act of 1918: Treasury Dept., U. S. Internal Revenue, pp. 31-33, 1919.

that even where there is not encroachment of water or oil the depletion is not precisely represented by the gage readings, though the errors are generally so small that they may be ignored. For example, where the pressure declines from 1,000 to 500 pounds, the gas is not exactly half gone, for the reason the pressures referred to are gage readings and to each should be added the pressure of the atmosphere —for most fields about 14.4 pounds to the square inch. The fraction remaining in the ground then becomes 514.4/1014.4.

"Account should also be taken of the pressure at which wells are abandoned in the field or district.

"If wells can not be operated with profit after the pressure has declined to 25 pounds gage reading (39.4 pounds absolute), then the percentage of recoverable gas remaining when the pressure has declined from 1,000 to 500 pounds gage reading is not one-half or even the fraction 514.4/1014.4 but 475/975. The difference in the fraction where pressures of several hundred pounds are involved is not great and scarcely worth considering in view of the other errors which are certain to affect the result. However, after the pressure has declined to a low figure, the matter of correcting the fraction becomes of considerable importance. Thus, if the pressure of abandonment is 4 pounds gage reading, and during the year the average closed pressure of a pool has declined from 10 pounds to 5 pounds gage reading, five-sixths instead of one-half of the recoverable gas has been withdrawn.

"Still another refinement that has, as a rule, more theoretical than practical value may be worthy of consideration in certain instances. This arises out of the fact that gases do not expand precisely as the pressure decreases, and that even if the size of the natural reservoir remains fixed the pressure does not decline in exact proportion to the amount of gas removed. The difference amounts to only a few per cent and is greatest for high pressures. In the decline from 1,000 to 500 pounds per square inch the gas expands several per cent more than would be calculated by a strict application of Boyle's law, and in a decline from 1,500 to 1,000 pounds the departure is still greater. The correction varies from field to field because of the different constitution of the gases, though since most natural gases consist largely of methane the variations on account of differences in gases are not great.

"A fourth detail of refinement arises out of the fact that on the average more gas is marketed for 50 pounds of decline in pressure after the pressure has reached 100 pounds or less than an equal decline while the pressure is high, as, for example, 1,000 pounds per square inch. Also the expense of marketing gas after the pressure has become low is greater than when it was high, largely because of the necessity of installing compressors to push the gas through the pipe lines to the consumers. These two considerations have a tendency to balance each other and, with certain exceptions, will not be of sufficient importance to warrant an attempt to apply the corrections.

METHOD OF GAGING

"In using the closed-pressure method of estimating depletion, the method of gaging is of vital importance and in many fields is not carried out with sufficient care. Care should be taken to make sure that the gage is accurate, testing it before and after attaching it to the well. If it must be transported far or is subject to much jolting in transportation, a gage tester should be taken along and used at the well.

"Care should also be taken to empty the well of oil and water by pumping, blowing, or siphoning before attaching the gage, for any liquid in the hole will lower the closed pressure reading.

"The well should be closed long enough to allow the pressure to build up to its maximum. The length of time necessary for this purpose varies a great deal from field to field and well to well. The well should remain closed until the pressure will not build up more than 1 per cent in 10 minutes. Ordinarily, 24 hours will be sufficient for this purpose, but for some wells several days or even a longer period will be required, owing to the slowness of equalization of pressure in the sand."

APPLICATION AT STAUNTON

As application of the closed-pressure method to any one well at Staunton might not give the desired result, most of the wells should perhaps be tested at the same time. What the closed-gage pressure at Staunton was in May, 1919, is not known. It might be higher than the pressure curves would lead one to suppose. It is evident, however, that starting at a rock pressure of 160 pounds the present pressures indicate that by far the greater part of the gas to be expected from the producing gas sands has been withdrawn.

It is worthy of note that the original ratings of producers (see Table I) were greatly in excess of their actual productions. To illustrate: wells No. 1, 2, and 3 had a combined rating of 38,900,000 cubic feet per 24 hours. These wells produced, at their highest, approximately 38,000,000 cubic feet during the whole month and they averaged per month in 1917 about 20,000,000 cubic feet or 1/58th of the original rating. The other figures show similar results to a greater or less extent, a notable exception being well No. 11.

WATER ENCOUNTERED AND ITS EFFECTS

The log of well No. 8 above shows a water sand at an elevation of 92 feet above sea level, another at an elevation of 44 feet, and a heavy water at an elevation of 9 feet. The water in this hole was plugged off and a good flow of gas obtained.

Other wells that struck water in or near the productive area are: No. 21, elevation 99 feet; No. 20, elevation 91 feet; No. 19, elevation 96 feet; No. 30, elevation 67 feet; No. 11, elevation 86 feet; No. 24, elevation 85 feet; No. 27, elevation 75 feet; No. 23, elevation 86 feet. It is doubtful if any of these wells reached the lower waters, encountered at elevations of 44 feet and 9 feet in well No. 8.

In well No. 21 the water was sufficient to drown off the gas after being allowed to stand and is no doubt flooding the sands locally. Well No. 20 after standing for months, had about 200 feet of water in the hole when cleaned out in May, 1919. The sands here were evidently subjected to water under a high head. Well No. 19 was still standing with a large head of water, not having produced for months, and the sands were unprotected. Well No. 30 was a dry hole. Well No. 11 blows off the small amount of water it makes through a one-inch perforated pipe. Well No. 24 was shot for oil and did not prove to be a producer of either oil or gas. No. 23 had a 3-foot plug of cement put in the bottom of the hole and arrangements were being made to put this well on pumping. Well No. 27 is plugged. No doubt the amount of water made by these wells is relatively small and shows up on accumulation. However, where allowed to accumulate, it locally must be flooding the sands, especially with the gas pressure decreased. It is understood to be sweet water.

Farther away from the producing area wells No. 39, 37, 36, and other dry holes struck water, most of them going into the heavy salt water above the "Big Lime." It is doubtful if these wells caused any flooding of the sands that would affect the producing area.

Until late in 1918 only two wells not mentioned above were affected by water trouble. Well No. 9, after having one inch perforated tubing installed, gave little trouble until the above time. Well No. 4 had a leaky casing and this was remedied by putting in a 4-inch string.

The usual procedure is to land the casing (6½ inch) on top of the gas sand; a few wells have wall packers. No doubt in most wells the nature of the casing seat lets some water into the hole. The producing wells at first easily blew off the small amount of water made, but when the pressure dropped below 20 pounds, the water became more evident. Late in 1918 this stimulated considerable installation of two-inch tubing with packer and anchor, and a "T" placed at the top of the sand for an opening. Wells No. 3, 15, 16, 7, 6, 13, and 18, all producers, had been tubed in the spring of 1919, as had also wells No. 20, 23, and 19, not then turned into the pipe line. The other producers continued to give gas from the casing head, some being hampered as the pressure decreased. With low pressure, a relatively small quantity of water soon heads off and traps the gas. Those wells that had not been drilled into water, when cleaned out after standing some time, showed only 20 to 40 feet of water in the hole. It seems that the water which began to make trouble late in 1918 was relatively small in amount.

There is no evidence to show that water came up the dip of the sand from the edges of the dome. It would appear that the water has not as yet encroached on the gas sand or to any considerable extent been a factor in the falling off of the gas production; rather, it came into prominence at the falling off of the gas pressure. It is now a source of trouble to the well owners, and those cases of indifference in well procedure that exposed the sands to water are now more likely

to bring about a condition that will make the recovery of the gas still remaining in the sands impracticable or very difficult.

If the load on the pool is lessened the gas pressure may build up somewhat and the installation of bleeders on the tubing might handle the water. If it should not, it would be necessary to employ some system of pumping off the water before it gains much head.

FUTURE DRILLING CONSIDERATIONS

Present Gas Sand

It is evident that the bulk of the gas has already been drawn from the present gas sand. The excessive number of wells has no doubt increased the waste. The pool has taken too big a load, and the very short stimulation brought by new wells only hastens exhaustion. In view of the nature of the structural uncertainty in the SE. ¼ sec. 24, the reappearance of good oil and gas shows in wells Nos. 11, 24, and others after the dry holes between there and the central group, and the behavior of the gas in well No. 11, suggesting that it may be more isolated from the central group than has been assumed, would indicate that a doming may occur along the continuation of the anticlinal axis toward the southeast. A well in or near the SE. ¼ SE. ¼ sec. 24 or close in to the common corner in sec. 25, Dorchester Township, and secs. 19 and 30, Staunton Township, would test the possibility for shallow oil or gas. If the doming occurs here, most of the discussion to follow on oil possibilities for the known dome would be applicable. Northwestward near the SE. ¼ sec. 10, a well might be expected to strike gas, but it would doubtless share in the flow from the northwest group. With the above exception in and near the SE. ¼ SE. ¼ sec. 24, it would not seem advisable to drill any more for this shallow gas in secs. 10, 11, 12, 13, 14, 15, 22, 23, and 24.

What is wanted is an isolated dome similar to the one now known. With the possible exception noted above, nothing in the area covered by this map (Plate I) indicates favorable structure. The possibility of similar domes outside the area covered by this map can not be discussed, as the working up of these notes gave no new information.

Known Horizon of Oil Shows

On the top of the dome oil may occur in commercial quantities closely underlying the productive gas sand. At Carlinville, oil was found in a sand which in places seemed to be a continuation of the gas sand, and in other places was found as much as 40 feet below the gas sand.[1] At Staunton due to the lack of detailed logs and also to somewhat different conditions, a study of this point is not decisive, but a similar underlying sand seems to exist here. Wells No. 23, 27, 28, 20, 21, 11, 24, 30, and 8 showed oil at an average depth of 246 feet below the top of No. 6 Coal, while the average depth of the gas sand is 218 feet below. Of these wells, the No. 6 coal in well No. 30

[1] Lee, Wallace, Oil and Gas in Gillespie and Mount Olive quadrangles: Ill. State Geol. Survey Bull. 31, p. 71, 1915.

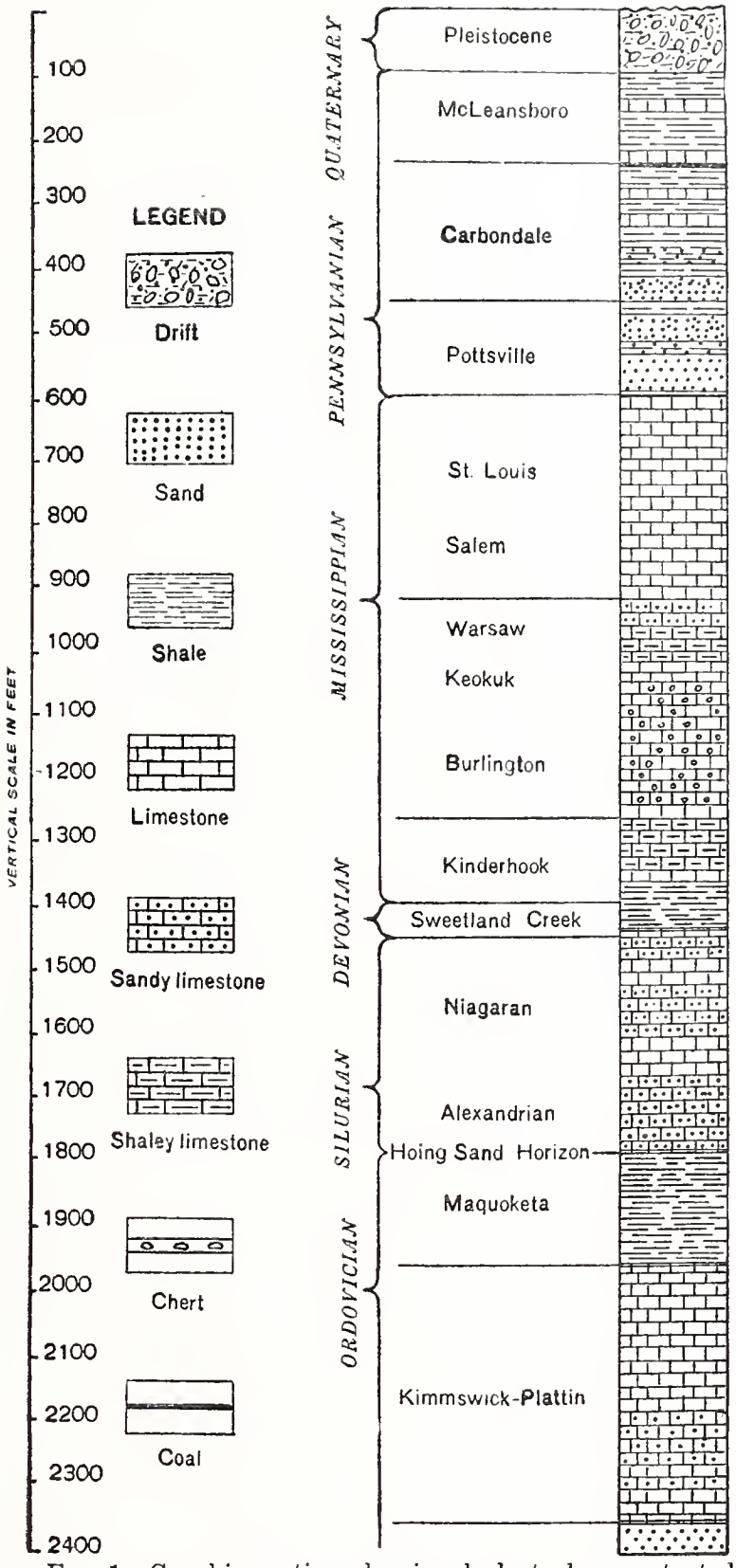


FIG. 1—Graphic section showing beds to be penetrated in deep drilling for oil in the vicinity of Staunton.

is at an elevation of 352 feet and the hole was dry, the sand being very broken. In well No. 21 the coal has an elevation of 356 feet and the lower sand has not been tested properly for oil. Nos. 11 and 24 had good oil showings, No. 24 having been reported as making 4 barrels on the beam after being shot. With the exception of perhaps Nos. 24, 25, and 26, which proved unproductive, no wells having been shot.

A flow of gas was found in well No. 19 at 255 feet below No. 6 coal which is the horizon of the oil shows. Several other wells, Nos. 12, 7, 6, and 22, went approximately deep enough to test this horizon without recording oil. But on the whole it would seem that this oil possibility deserves a proper test. A well within and near the 360-foot coal contour could perhaps mud or case off the gas sand and give this horizon a good test.

Deeper Possible Horizons

It should be noted that in drilling through the present gas sand to deeper horizons, precautions should be taken to protect the producing gas sand and horizons to be tested, from water.

The question of oil possibilities at deeper horizons is pertinent. The Staunton dome being the only known favorable structure in this immediate area presents the logical location for any deeper wells to test lower horizons. Although unconformities may exist, it has been found in many cases in this State that structure indicated by the "Coal Measures" is found in the underlying strata to exist in sufficient degree to have caused the accumulation of oil. This is exemplified on the western side of Illinois in the Plymouth pool in McDonough County,[1] where the mapping and description of a dome on No. 2 coal led to the development of an oil pool in the "Hoing" sand occurring there at the base of the Niagaran (Silurian) limestone.

STE. GENEVIEVE LIMESTONE

As shown in other parts of the State, the next likely horizon for oil to be expected at Staunton below the known oil shows is that of the Ste. Genevieve limestone ("green oil" horizon) which is the uppermost formation of the "Big Lime." It is not known whether the Ste. Genevieve occurs under the Staunton dome. Weller[2] shows 48 feet of Ste. Genevieve in the cliffs at Alton, about 20 miles southwest of Staunton, but according to Worthen[3] the beds thin out to the north. Well No. 8 in sec. 15 of Dorchester Township, wells in Bond County to the southeast, wells in Madison County to the south, wells in Montgomery county to the east, and wells near Carlinville to the north do not show whether the Ste. Genevieve is represented. The productive beds in this formation are sometimes as thin as 2 or 3 feet and might easily be overlooked where they are not productive. The log of well

[1]Hinds, Henry, Oil and Gas in the Colchester and Macomb quadrangles: Ill. State Geol. Survey Bull. 23, pp. 11-13, 1914.

[2]Weller, Stuart, Mississippian Brachiopian: Ill. State Geol. Survey Monograph I, p. 22, 1913.

[3]Worthen, A. H. Geology of Jersey County: Geol. Survey of Ill., Vol. III, Chap. VI, p. 111, 1868.

No. 8 given on a previous page showed green oil at 565 feet. Only two wells, Nos. 8 and 29, close in on the dome reached the "Big Lime." Others, Nos. 34, 39, and 37, some distance away, also reached the "Big Lime."

The following table illustrates the irregularity in the interval between the eroded surface of the "Big Lime" and the top of No. 6 coal.

Well number	Section	Township	Elevation top No. 6 coal	Elevation top "Big Lime"	Interval
			Feet	*Feet*	*Feet*
8	15	Dorchester	332	—25	357
29	24	Dorchester	330	—10	340
39	25	Dorchester	339	—77	416
34	23	Dorchester	321	—104	425
37	19	Staunton	.....	.....	386

It is not known whether the interval is less under the dome than elsewhere and these few figures are not sufficient basis for a generalization.

On the dome the "Big Lime" should be expected at about 375 feet below the top of No. 6 coal. The thickness through which the Ste. Genevieve has given production in other parts of the State is about 85 feet. A well should go about 100 feet into the lime to test this horizon. On the top of the dome where the surface elevation is about 610 feet and that of the coal 360 feet, this would require a hole approximately 725 feet deep.

NIAGARAN LIMESTONE AND HOING SAND

The next lower horizon where oil might be expected is in or under the Niagaran (Silurian) limestone. Under the "Big Lime" come the Kinderhook shales and the Devonian shales, followed by a limestone which is probably the Niagaran. In well No. 8, previously cited, the limestone at 1450 feet is doubtless Niagaran[1]. Near Carlinville the limestone at this horizon, encountered at 1395 feet, has a thickness of 340 feet. It is thought that most of this is Niagaran, although some Alexandrian might be expected. North of Edwardsville this limestone was encountered at 1450 feet and appears to be about the same thickness as at Carlinville. In Bond County and near Litchfield it is questionable if the limestone called "Trenton" is not more probably Silurian. Otherwise the Silurian limestone horizon at those places shows only 25 to 30 feet. This point introduces an element of doubt about the thickness of the Silurian at Staunton; however, it may be expected to be about 325 feet thick. As the Mississippian and upper Devonian rocks at well No. 8 are 850 feet thick, and at Carlinville 825 feet thick, the top of the Silurian limestone should be expected at about

[1] It is possible that some thickness of Devonian limestone may occur at the top of this limestone horizon. However, the correct correlation of the upper part of the horizon is not pertinent to the discussion.

1475, and the bottom about 1800 feet below the surface in the S. ½ of section 14. Possibilities exist in the Niagaran limestone itself, and the "Hoing" sand of McDonough County comes immediately below the Silurian overlying the Maquoketa shale. Well records show that this sand is absent in many places in western Illinois, and also where present it is sometimes unproductive. However, this presents a possibility.

"TRENTON" LIMESTONE

The next and lowest likely oil horizon is that of the "Trenton" (Kimmswick-Plattin) limestone. The additional depth to the top of this limestone below the Silurian depends on the thickness of the Maquoketa shale. The Maquoketa is 165 feet thick at Jerseyville, about 180 feet thick at Carlinville, 130 feet, more or less, near Edwardsville, and either 75 or 190 feet at Litchfield (depending on uncertainties in correlation). The Maquoketa might be expected to be approximately 175 feet thick at Staunton. At Carlinville the "Trenton" was reached at 1914 feet and penetrated for 193 feet. Its physical characters were not promising for oil possibilities as it was a non-dolomitic limestone which seems to be the character of the upper portion of the "Trenton" generally in this part of the State. To test the "Trenton" a hole should go through the lower portion, which is in some places dolomitic, and therefore has more favorable physical characters. The "Trenton" is about 340 feet thick at Jerseyville, and 350 to 400 feet thick in Madison and St. Clair Counties. It may be expected to be about 400 feet thick at Staunton. A hole should reach the top of the "Trenton" at about 1975 and the bottom at approximately 2375 feet below the surface in the S. ½ of sec. 14.

CONCLUSIONS

The logical place for tests of the lower horizons would be well within the 360-foot contour on No. 6 coal—in the southern half of section 14.

In the following table, the first column gives the probable depths necessary to test the different underlying horizons in S. ½ sec. 14, Dorchester Township; the second column using No. 6 coal bears no relation to the surface elevation and therefore applies to the whole Staunton area.

Summary of probable depths to underlying horizons in S. ½ sec. 14, Dorchester Township

Horizon	Expected depth below surface	Expected depth below top of No. 6 coal
Top of "Big Lime"	625	375
Test of Ste. Genevieve limestone	725	475
Top of Silurian limestone	1475	1225
Test of Silurian and of Hoing sand horizon	1800	1550
Top of "Trenton" limestone	1975	1725
Test of "Trenton" limestone	2375	2125

SUMMARY

(1) The producing gas wells have followed very closely the structure, as shown by the contours on No. 6 coal, being influenced locally by the physical characters of the sand.

(2) The decline in gas pressure and flow has been very rapid and the present producing sands are nearing exhaustion in this locality.

(3) The sands have high porosity in places. They seem to be persistent, and if a doming similar to the known dome is found elsewhere in this general area, it may reasonably be expected to show the same horizon productive.

(4) Water has not so far been an important factor in the pool's decline. With the decrease of gas pressure the sand exposed to water is now more liable to be damaged.

(5) Too many wells are already tapping the present gas sand and no more wells should go after this gas in sections 10, 11, 12, 13, 14, 15, 22, 23, and 24 (with the exception of sec. 24 discussed above). The "oil show" horizon closely underlying the gas sand should be tested near the 360-feet coal contour. Lower possible oil horizons may be expected at depths indicated in the table given above under Conclusions.

ADDENDUM

Since the above paper was written, a location for a well given to Mr. M. F. Sherman of Staunton, on a lease held by him, resulted in the bringing in of a gas well at the SE. corner SW. ¼ SE. ¼ sec. 24. As shown under "Future drilling considerations," this general locality was the only one recommended for further gas-sand drilling. It is hoped that this area will be drilled carefully. Detailed logs of drilling in the following places will furnish information as to the "lay" of the beds: SE. corner SE. ¼ SE. ¼ sec. 24, NE corner SE. ¼ SE. ¼ sec. 24, SW. corner NE.¼ NE. ¼ sec. 25, all in Dorchester Township, and perhaps SE. corner SW. ¼ SW. ¼ sec. 19, Staunton Township. Subsequent drilling should depend upon the results of tests in these localities. Tests of this ground for shallow oil could then be located with greater assurance. As far as present knowledge goes, oil tests near the center SW. ¼ SE. ¼ sec. 24, or near the SE. corner NW. ¼ SE. ¼ sec. 24 seem worth while. A well to test for oil should be prepared to mud off any quantity of gas encountered, thus protecting the sands and making it practicable to go through the gas sand.